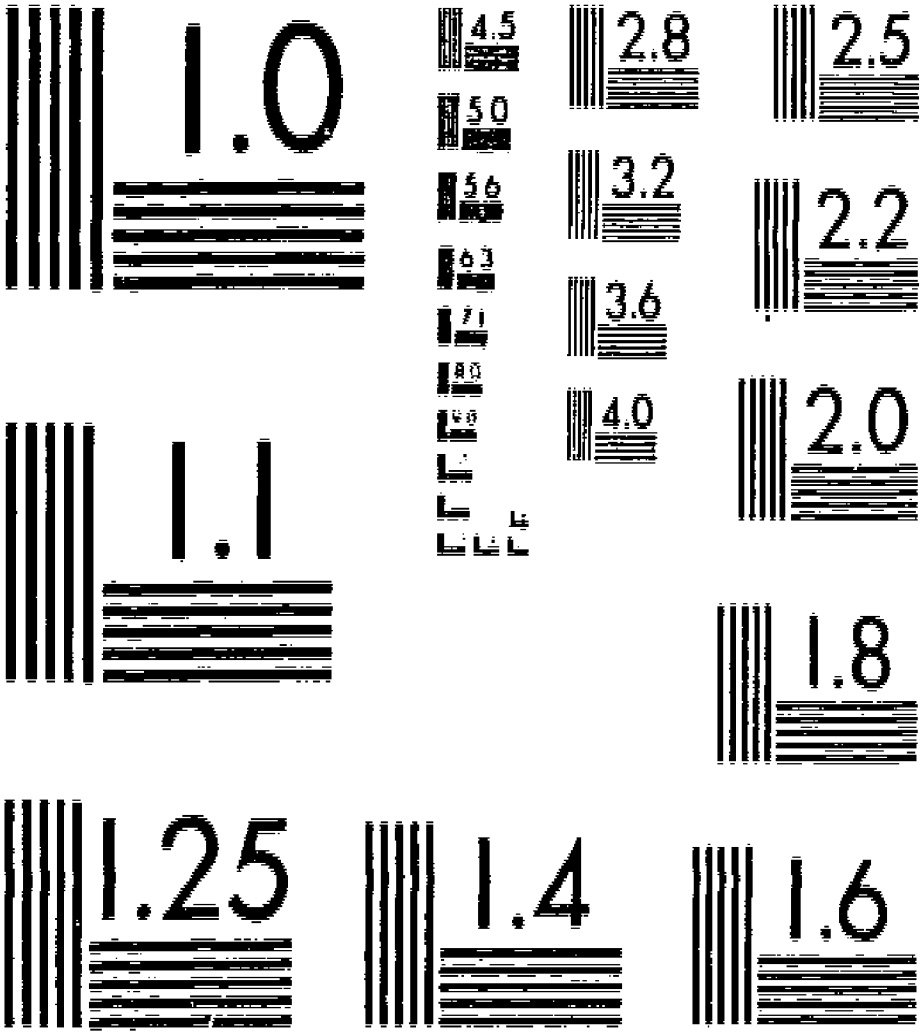

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ABSTRACT

College biology students, using an audio-tutorial format, participated in a study in which instructional time and quality were structured to accommodate for differences in students' abilities to attain their potential (mastery strategy). Students in the experimental group who failed to achieve 80 percent on an evaluative checktest for a subunit were required to participate in some corrective measure: repeating the study of the subunit, studying the objectives, reading a portion of a manuscript, conferring with the instructor, or some combination of these. The control group was not required to achieve mastery on any of the subunits. At intervals during the course both groups were examined and the composite score of the exams, The Biology Achievement Test, was compared for the groups. Both groups had been pretested, with analysis of covariance used to account for initial differences in the two groups. The achievement of the experimental group significantly exceeded that of the control. Although students in the experimental group spent significantly more time in course work, primarily in the laboratory, than did those in the control group, they also exhibited a more positive reaction to the course. (Author/CP)

FINAL REPORT
Project No. 1-E-041
Grant No. OEG-5-71-0034(509)

MASTERING SUBJECT MATTER THROUGH AUDIO-TUTORIAL TECHNIQUES FOR TEACHING BIOLOGY

Phillip D. Sparks
Wisconsin State University
La Crosse, Wis. 54601

August 1971

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

SUMMARY

Most students in a college biology course are capable of achieving at a level greater than what is actually observed. Since students' abilities are variable in a normal population and instructional time and quality is generally the same for those students, the result of most teaching endeavors is to obtain a normal distribution of marks at the end of the term. This paper reports the results of a study in which the instructional time and quality was structured to accommodate differences in students' abilities to attain his potential. This alternative structure for learning is called the mastery strategy and is patterned after the thoughts of Dr. Benjamin Bloom. The mastery strategy involves programming each unit of a course into small conceptual subunits, and demanding that the student be able to achieve 80% on an evaluative checktest covering the objectives of a subunit before he continues with any subsequent subunit. This level was considered as mastery. Should a student fail to achieve mastery on one of the subunits he was asked to take part in some corrective measure depending upon the diagnosis of the instructor. The measures could include one or a combination of the following: repeating the study, studying his objectives, reading a portion of a manuscript, and a personal conference. After completing the prescribed activity he repeated the evaluation using a different version of the checktest.

A control group of students took the course and were exposed to the same material. The control group was not required to achieve mastery on any of the subunits. At intervals during the course both groups were given identical exams in order to compare the achievement of the control with the achievement of the experimental group. The composite score of the exams was called the Biology Achievement Test. A pretest was administered to both groups at the beginning of the term and was used in an analysis of covariance to adjust the Biology Achievement Test scores to account for initial differences in the two groups. The results showed that the achievement of the experimental group significantly exceeded that of the control.

Predictors of success in biology were evaluated. High school rank was found to be a superior predictor to either the pretest or to any portion of the American College Test. The students in each group were then subdivided into low ability (lower 27%) and high ability (upper 27%) subsections based on the high school rank to evaluate the effectiveness of the mastery strategy on both of these types of students. It was found that the mastery strategy was not significantly more effective for either the low or the high ability groups, but a variation was evident in a middle ability group.

Grade distribution of the experimental group on the achievement tests were not significantly different for the control group; however, a general observation reveals an upward skewing of the marks in the experimental group.

Time devoted to the course was analyzed for students in each of the two groups. Students in the experimental section spent significantly more time than the control group. The differential was primarily due to time spent in the laboratory.

A questionnaire indicated that the students in both groups had a

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favorable impression of the course and its organization. The reaction of the experimental group seemed to be more positive than the control. Furthermore, the students in the experimental section hypothesized that the mastery strategy had aided their achievement, a hypothesis that was supportable by actual data.

INTRODUCTION

The Philosophy of Mastery

At the beginning of each school term most teachers expect that about one-half or more of their students will fail to adequately master the objectives of their course to the extent that they could be called "good students". Traditional educational policies and grading practices have encouraged this waste of academic and human resources. Such a system reduces both the aspirations of students and teachers. (Bloom, 1968)

The author found Bloom's thought noted above to be descriptive of his own attitude in coordinating a large general biology course which enrolls about 2300 students per year. In the fall of 1968 behavioral objectives were constructed for the course but with the realization that only about one-third of the students finishing a semester of general biology would be able to achieve enough (75%) of them to be called "good students". The majority of the other two-thirds were capable of mastering the subject matter to the extent of being "good students" but the strategy for motivating this level of performance was not available. The hypothesis was formed that, *if* such a strategy became available *then* achievement would be significantly improved.

A Brief History of Mastery

Widespread interest in developing mastery strategies for learning has evolved since 1968 when Bloom (1968) proposed a working model for mastery learning. However, there were at least two major attempts to produce designs for mastery learning as early as the 1920's (Washburne, 1922; Morrison, 1926). These two programs did not prove to be popular because technological innovations needed to sustain a successful strategy were not available (Block, 1971). The idea was reborn in the 1950's with the advent of programmed instruction which was based on the concept of Skinner (1954). Even though programmed instruction proved to be a useful tool for mastery learning it alone was not a workable strategy. The first useful conceptual model was outlined by Carroll (1963) who recognized that the aptitude of a student was correlated to the time required to achieve an objective. Bloom's (1968) working model is based on the scheme conceived by Carroll. In general a strategy designed for mastery learning takes into account individual differences in learners and relates these variations to the teaching process. Typically an educational program provides a group of students with the same type and quantity of instruction regardless of the individual variations which may exist within the class. On the other hand an educational program designed for mastery learning will provide for variations in the learning rate and aptitudes of its students. The kind and quality of instruction and the amount of time available will reflect the needs of each student. *If* such alternatives are available, *then* the majority of students may be expected to achieve mastery of the subject. Existing strategies which provide these types of alternatives have not been widely tested. One report concerning a course on test theory noted that the number of A's earned increased from 20% prior to implementation to 80% after. This represented a change of two standard deviations and was shown to be highly significant (Airasian,

1967). In a study involving algebra classes in mathematics 75% of the students using the mastery strategy achieved the mastery criterion of an A or B grade whereas only 39% of the control group achieved the criterion mark (Collins, 1969). On the other hand, a study by Welser, et al.(1970) indicated that no significant difference was evident as a result of implementing the mastery strategy in a course in veterinary anatomy. After analyzing 91 comparative studies of various college teaching technologies Dubin and Taveggia (1968) point out that generally there is not a measurable difference among distinctive methods of college instruction when evaluated by student performance on final examinations.

The control and experimental groups of many studies to date evaluating the mastery strategy have involved students from sequential years and both groups have not been students concurrently enrolled in a program. Even though such tests may be valid, the study would be more reliable if one could be more assured that the selection of the control and experimental group were from the same population.

The Problem

The general biology course is taught at La Crosse using the audio-tutorial (AT) method of instruction (Appendix A). When compared with conventional methods, student achievement is improved using the audio-tutorial technique, (Sparks and Unbehaun, 1971). The audio-tutorial format permits the student to learn or master individual segments of the biology program in sequence. In practice, however, the student typically chooses to listen to a tape in its entirety, taking notes to study later without mastering the individual segments. As he proceeds he leaves the study center without really knowing whether or not he has achieved the objectives prescribed for him. In short, the student's behavior is very much like he follows in a conventional classroom. Consequently, a strategy for mastery learning should be particularly beneficial to biology students using the audio-tutorial format.

METHODS

General Design

The mastery strategy was implemented during the second semester of the 1970-71 academic year. The experiment was divided into two basic groups of students, an experiment group (MAST) and a control group (CONT). The groups were composed of students registering for two separate general assemblies during the registration period. Students were permitted to register for the general assembly of their choice but were not told that any experiment or procedural differences were involved. In an attempt to get similar students in both groups, the general assemblies that met during consecutive hours (9:00 and 10:00 Mon.) with the same instructor were used for the study. The control section enrolled 183 students and the experimental section enrolled 163 students.

The control group was handled in accordance with Appendix A. Each week the student attended a general assembly, was given a set of behavioral objectives, went to independent study (audio-taped lab) and attended a small assembly. The course was divided into fifteen units. Each unit was one week long. The experimental section was handled the same way except that each week's unit was further broken down into individual conceptual subunits similar to the mini-course format (Postlethwait, 1969). Each unit consisted of from two to three conceptual mini-courses.

After the student completed each mini-course he was required to take a short diagnostic checktest covering the objectives of that mini-course before continuing with subsequent work (For sample checktests see Appendix B). If the student failed to achieve mastery (80%), the student was asked either to visit the consultant in the laboratory for a short tutorial session or to relisten to the segment of the tape covering the unmastered mini-course, depending upon the diagnosis of the lab instructor. If a student failed on his second try to achieve mastery he was required to make an appointment with an instructor for an extended tutorial session. At the end of the tutorial session the instructor evaluated the student's level of achievement and could declare the mini-course satisfactorily completed. Any student who successfully completed all the mini-courses during the semester received 100 points for a quiz score for the term.

For each mini-course which was not satisfactorily completed the student lost a proportionate amount of 100 points. The detailed operational guidelines which were supplied to the students in the experimental section are shown in Appendix C. The students in the control section had the opportunity to earn the same 100 quiz points as those in the experimental section; however, the control section was quizzed during the general assembly after each weekly unit had been completed. No performance level on quizzes was required for the control section.

Achievement Evaluation

Four times during the semester both groups were given major hour long examinations that contained a total of 332 common test itesm known as the Biology Achievement Test (BAT). Some sample questions are shown in Appendix D. The tests were judged to be valid by a panel of instruc-

tors that worked in the course. The test items were constructed to evaluate whether or not the behavioral objectives had been achieved.

During the first meeting of the class a pretest was administered to both groups to evaluate the comparable achievement level of the sections prior to being exposed to the treatment. Scores on the Biology Achievement Test (BAT) were adjusted, based on the pretest, using an analysis of covariance (Winer, 1962). The student recorded his responses to test items on an IBM 630 scoring form which was scored using an IBM 534 optical scanner and card punch. The IBM 1130 computer was used for the analysis described in this paper.

The items on the BAT were divided into eleven topical sections to check if the mastery concept proved more valuable to certain segments of the course than others. The topical sections are listed in Table 2. A $\hat{z}$ test was used to analyze the difference of the means for the control and the experimental group on each of the topical sections (Downie & Heath, 1959).

Ability Grouping

The hypothesis that the mastery teaching format is more valuable to low ability than high ability students was tested. In order to divide the students into low ability and high ability groups a predictor of success on the BAT was researched. Correlation coefficients were calculated for the BAT and seven other measures which were available at the beginning of the course (Downie & Heath, 1959). Using the correlation coefficients a probability indicator was calculated for each measure and the BAT to evaluate the usefulness of each measure as a predictor (Downie & Heath, 1959). The seven measures included in the study were high school percentile in graduating class, pretest, and five components of the American College Test (ACT): English, mathematics, social sciences, natural sciences, and the composite score. High school percentile consistently had the highest correlation with the BAT. Both the control and the experimental groups were divided into ability groups. The top 27% of the students in each section based on high school percentile was considered to be the high ability group and the bottom 27% the low ability group. A third group, the middle 46%, was also included. An analysis of covariance comparing the control and the experimental group of the low ability group was performed and an identical analysis was carried out on the middle and the high ability groups. Again the pretest was used to adjust the scores of the control and the experimental sections on the BAT.

A second grouping of students was established based upon the pretest. The pretest was used to evaluate initial knowledge in biology. Students were again divided into the lower 27% and the higher 27%.

Since the mastery strategy was designed to increase the number of students which could be called "good students", achieving above 75%, an analysis of the grade distribution for the control and the experimental group was conducted. The achievement levels required to receive specific marks for the course were as follows: A = 85-100%, B = 75-84%, C = 60-74%, D = 50-59%, F = below 50%. The analysis was designed to answer two questions: one, is the grade distribution based on the BAT different for

the control and the experimental group, and two, are the numbers of students above 75% (good students) different for the two groups. A chi-square test of independence (2 X 5) was applied to the grade distribution of the two groups to evaluate the first question. A similar test was used to analyze the second question except all students who achieved above 75% in each group were lumped together and all students who achieved below 75% were lumped together (2 X 2).

Attitudes

An attempt was made to compare the attitudes about the course of the control and the experimental group using a questionnaire. The questionnaire was administered during the last meeting of the class and is shown in Table 8. In the control group 150 students completed the questionnaire, whereas in the experimental group 115 students completed the form. Each item was analyzed using the chi-square technique for significance to see if the distribution of answers were different for the two groups. For items which had more than two choices, a second chi-square test was performed. On the second test, data were lumped in order to find if one choice or group of choices was selected more by one group than the other. Three items at the end of the questionnaire were asked of the experimental group only, consequently a statistical analysis of the data for those items was not possible.

Time Study

Students were asked to record the time spent in the laboratory after each visit on a registration card. Each week the time spent by each student in the lab was recorded and at the end of the semester a comparison of lab time was conducted. A $\hat{z}$ test for significance was performed using the average lab time spent per student per week as the data. Also the students were asked on the questionnaire how much time they devoted to the course in addition to the laboratory so that the total time commitment could be compared for the two sections. The number of students in each section who did not attend lab during a week was also noted.

Students Excluded from Study

A student was excluded from the study if he did not complete all the evaluation tests which made up the BAT. Presumably he was excluded if either he dropped the course or he took a make-up evaluation on one of the major tests. A chi-square test of independence was applied to test the hypothesis that the proportion of subjects excluded from the study were not significantly different in the two groups. A second chi-square test to test the hypothesis that the number of students dropping the course in each section was not significantly different was also performed.

RESULTS AND ANALYSIS

A series of hypotheses were established and tested statistically in accordance with the methodology already noted. This section presents the results of those tests.

Achievement

A total of 332 common test items made up the Biology Achievement Test (BAT). These items were administered to both the control and the experimental groups. The scores of the BAT were adjusted (BAT-ADJ) for initial differences in achievement levels based on a pretest (PRET) using an analysis of covariance.

Hypothesis 1: Achievement of students in the control (CONT) group was not significantly different from achievement of students in the experimental group (MAST).

Result 1: The hypothesis was rejected.

Mean scores ($\overline{X}$) on both the Pretest and the Biology Achievement Test are shown in Table 1. Results indicate that there is a difference in the two groups after the treatment. The analysis suggests that the mastery strategy was effective in helping students achieve the objectives for the course.

Table 1. The effect of Mastery on Achievement of Students

	PRET $\overline{X}$	BAT $\overline{X}$	BAT ADJ $\overline{X}$
CONT	20.36	234.96	234.45
MAST	19.98	242.49	*243.05

*Significant at the 95% confidence level

Even though the adjusted mean for the experimental group was only eight points greater than for the control group, the difference was significant. What one must keep in mind when contemplating implementing the mastery strategy is, How much of a difference should one expect to find before it is worth the effort? Although a differential commitment for the staff working with the mastery section was not recorded, the students in the mastery section required more staff support primarily for administering and evaluating the formative checktests in the laboratory. More allied support in terms of clerical and secretarial assistance was also required for the experimental section.

When the BAT was divided into eleven topical sections it was found that the mastery strategy was more effective for some topics than others. The results are shown in Table 2.

Table 2. The Effect of Mastery on the Achievement of Students on Various Topics of Biology

	Total $\bar{X}$	Pretest	Chemistry	Cell Structure	Transport Mechanisms	Metabolism	Control Mechanisms	Cell Division	Plant Reproduction	Animal Reproduction	Genetics	Evolution	Ecology
CONT	235.0	20.4	46.6	16.6	15.1	31.6	16.5	9.7	14.3	24.3	14.3	11.7	15.7
MAST	242.5	20.0	*48.4	16.8	15.6	32.8	17.2	*10.5	*15.5	*25.9	13.7	11.8	15.3
MXSC	332.	52.	59.	23.	21.	50.	24.	14.	23.	38.	21.	15.	21.

MXSC = Maximum Score

* Significantly different at the 95% confidence level

Hypothesis 2: Achievement of students in the control group was not significantly different from that of the experimental group on any of the topical sections.

Result 2: The hypothesis was rejected for the topical sections entitled chemistry, cell division, plant reproduction, and animal reproduction.

All the higher means where significant differences were apparent belonged to the experimental (MAST) group. The control group failed to significantly excel on any of the topics.

It is interesting to compare the results of the analysis of covariance (Table 1) and the BAT-Pretest combination (Table 2). If one looks at the BAT scores themselves, no signicant difference in the two groups is apparent. Likewise if one looks at the Pretest, no significant difference in the two groups is apparent. However when the BAT scores are adjusted using the analysis of covariance for some slight initial variations in the pretest, a significant difference is attained.

Ability Grouping

In order to find a significant predictor of success correlation coefficients and their accompanying probability indicators were calculated for the BAT and seven measures which were available at the beginning of the course (Table 3).

Table 3. Correlations of Various Predictors with the Biology Achievement Test (BAT)

	Correlations		Probability Indicator	
	CONT	MAST	CONT	MAST
BAT - Pretest	.23	.35	.03	.06
BAT - English (ACT)	.53	.24	.15	.03
BAT - Math (ACT)	.51	.45	.14	.11
BAT - Social Sciences (ACT)	.55	.35	.17	.06
BAT - Natural Sciences (ACT)	.48	.36	.12	.07
BAT - Composite Score (ACT)	.64	.44	.23	.10
BAT - High School %	.57	.59	.18	.19

The most consistent predictor of success on the BAT was the high school percentile rank. For example the probability indicator for the BAT and the rank for the control group was .18. This statistic means that using the high school percentile, success on the BAT can be predicted 18 percent more accurately than when not using a predictor. Note that the pretest was not a relatively good predictor of success. Using the best

predictor, high school rank, both the control and the experimental group were divided into a low ability, a high ability and a middle ability group in an attempt to see which student the mastery strategy affected the most. The results are shown in Table 4.

Table 4. The Effect of Mastery on Various Ability Students Based on High School Rank

	PRET $\bar{X}$	BAT $\bar{X}$	BAT ADJ $\bar{X}$
Upper 27% CONT	21.00	271.00	271.33
Upper 27% MAST	21.72	275.12	274.67
Middle 46% CONT	20.60	226.18	225.99
*Middle 46% MAST	20.15	241.53	241.75*
Lower 27% CONT	19.11	212.91	212.75
Lower 27% MAST	19.00	219.74	219.93

*Significant at the 95% confidence level

Hypothesis 3: The achievement of students in either the low ability group, the high ability group or the middle group is not affected by the mastery strategy when the ability grouping is based on high school rank.

Result 3: Hypothesis rejected for the middle group only.

The results indicate that the mastery strategy is not significantly helpful to either the low or the high ability group, but it was effective with the middle group. In evaluating this portion of the study one should keep in mind that even though the high school rank was the best predictor available, the probability indicator for both the control and the experimental group was less than 0.20.

Students were also placed into low and high groups based on their knowledge of biology when they entered the course. A pretest was used to assess their knowledge of biology at the outset. The results are shown in Table 5.

Hypothesis 4: The mastery strategy does not affect the achievement of students regardless if they enter the course with a relatively good background in biology or a relatively poor background in biology.

Result 4: The hypothesis could not be rejected.

The results in Table 5 suggest that the mastery strategy was not more valuable to students with relatively poor backgrounds in biology than the traditional AT format being used by the control group. Likewise the same conclusion is suggested for students with relatively superior backgrounds.

Table 5. The effect of Mastery on Groups of Students Based on the Pretest

	PRET $\bar{X}$	BAT $\bar{X}$	BAT ADJ $\bar{X}$
Upper 27% CONT	25.25	244.20	244.58
Upper 27% MAST	25.50	254.38	253.87
Lower 27% CONT	15.24	222.87	222.71
Lower 27% MAST	15.17	225.86	226.09

This study has already established that the achievement of the two groups was different. The mastery strategy did result in a significant improvement, but, did the mastery strategy significantly affect the grade distribution (Table 6)?

Hypothesis 5: The distribution of marks based on the BAT were the same for the control and the experimental groups.

Result 5: The hypothesis could not be rejected.

Table 6. The Percent of Students Achieving Specific Marks Based on the BAT

	CONT	MAST
A (85-100%)	16.9	11.7
B (75-84%)	20.6	32.4
C (60-74%)	43.8	44.8
D (50-59%)	13.7	9.7
F (Below 50%)	5.0	1.4

Even though there appears to be an upward skewing of marks in the experimental section the grade distributions are not significantly different. Since the mastery strategy is designed to increase the number of students above 75% the data were reanalyzed lumping all students above the 75% mark into one group and all those below 75% into another.

Hypothesis 6: The percent of students above the 75% achievement mark in the experimental group is the same as the number above 75% in the control group.

Result 6: The hypothesis could not be rejected.

Table 7. The percent of Students Achieving Above 75% on the BAT

	CONT	MAST
Above 75%	37.5	44.1
Below 75%	62.5	55.9

When a chi-square test of independence is applied to the data in Table 7 the experimental group does not significantly differ from the control. At this point the validity of the checktests must be questioned. It seems reasonable to assume that if the performance on the checktests was equal to or greater than 80% then the performance on the BAT should also have been equal to or greater than 80% for the experimental section, since both were designed to evaluate the extent to which the objectives had been achieved.

Attitudes

The utilization of the questionnaire had two objectives. 1) To evaluate the comparable acceptance of the course between the control and the experimental group, and 2) to determine to some degree the attitude of the experimental group toward the mastery strategy. The results are summarized in Table 8. Item 1 evaluates the acceptance of the audio-tutorial format of instruction. In general both groups accepted the audio-tutorial system of instruction. The students were somewhat handicapped in their choice by not having had the course using the conventional lab-lecture system to make a comparison; however, the students have been exposed to the lecture method routinely in other course work. Significantly more students of the experimental group favored the AT system. No attempt was made to determine why they favored the AT system. In a second chi-square test of the same data, choices "a" and "c" were combined so that these choices could be collectively evaluated against choice "b". Significantly more students selected choice "b" in the experimental section than in the control. One would expect the results of item 5 to be similar to item 1. Approval of AT by using both items is apparent; however, the response of the control and the experimental sections to item 5 was not significantly different. Questions about responsibility (item 2) and course organization (item 3) did not yield any significant differences. When students were asked to rank the course, their distribution of answers differed significantly (item 4). However, in the second test of the same item when the hypothesis that the groups did not differ in their response to choice "a" (the biology course was the best of the ones in which they were currently enrolled) was tested no difference was apparent. The opinion of the two groups concerning a biology requirement was not significantly different (item 6). The time spent studying for an exam was not different for the two groups (item 7), however, the experimental group did spend significantly more time in the independent study laboratory than the control group (item 8). This difference is also supported by actual data taken from time cards noted in Table 9. Also more of the experimental group spent less than one hour outside of class studying biology than did the control group (item 9). From the response to item 9 it might be assumed that the control group spent more out of lab time per student than the experimental group. However, the data in Table 9 shows that the difference is not significant.

Sampled student opinion indicates that the experimental group accepted the mastery strategy as useful (items 10, 11, and 12). Item 11 indicates that the students in the experimental section thought their performance on the BAT was improved because of the mastery strategy; their opinion is confirmed by the data presented at the beginning of this section.

Table 8 The Questionnaire

	I Percent of Students		II Percent of Students Combined Data	
	CONT	MAST	CONT	MAST
1. If the choice were mine to make again, I would prefer to take a Biology 100 course using:		*sig.		*sig.
a. a lab-lecture system of instruction	20	5		
b. an audio-tutorial system of instruction	75	93	75	93
c. I have no preference	5	2		
Total choice a and c			25	7
2. The AT course, more than any one of my other courses, helped me to develop a sense of responsibility for my own success				
a. true	64	72		
b. false	36	28		
3. The organization of this course is:				
a. the best of those in which I am presently enrolled	70	81	70	81
b. the worst of those in which I am presently enrolled	2	0		
c. somewhere in-between in organization	28	19		
Total choice b and c			30	19
4. I would rank Biology 100 as:		*sig.		
a. my best course this semester	34	46	34	46
b. my second best course this semester	44	47		
c. my worst course this semester	22	7		
Total choice b and c			66	54

*sig. = The responses of the two groups are significantly different at the 95% confidence level

Table 8 - continued

	I Percent of Student		II Percent of Students Combined Data	
	CONT	MAST	CONT	MAST
5. If made available, I would select sections of other basic studies courses which were taught by the AT method.				
a. yes----------	74	81		
b. no----------	26	19		
6. All students should be required to take a minimum of one biology course.				
a. yes----------	61	67		
b. no----------	39	33		
7. The time I spent studying for an exam was (other than ISS):				
a. less than 1 hour----------	5	9		
b. between 1 and 3 hours----	45	39		
Total choice a and b----------			50	48
c. between 3 and 5 hours----	38	34		
d. more than 5 hours--------	12	18		
Total choice c and d----------			50	52
8. How much time did you average in the laboratory each week?		*sig.		
a. less than one hour-------	4	1		
b. one to two hours----------	35	12		
c. two to three hours-------	45	41		
Total choice a, b, and c-----			84	54
d. three to four hours------	12	30		
e. more than four hours-----	4	16		
Total choice d and e----------			16	46

Table 8 - continued

	I		II	
	Percent of Students		Percent of Students Combined Data	
	CONT	MAST	CONT	MAST
9. During the week, in addition to work in the laboratory, I spent on the average:				*sig.
a. less than one hour working on biology outside the class---	34	50	34	50
b. between one and two hours working on biology outside the class----------	53	33		
c. between two and three hours working on biology outside the class----------	9	10		
d. between three and four hours working on biology outside of class----------	2	3		
e. more than four hours working on biology outside the class	2	4		
Total choice b, c, d, and e----			66	50
10. If the choice were mine to make, I would prefer to take a section of Biology 100 which:				
a. used the mastery strategy--		89		
b. did not use the mastery strategy----------		11		
11. As a result of the mastery strategy I feel that I:				
a. did poorer on the major exams than I would have by just taking weekly quizzes in General Assembly----------		10		
b. did about the same on the exams as I would have by just taking weekly quizzes in General Assembly----------		20		
c. did better on the exams than I would have by just taking weekly quizzes in General Assembly		70		

Table 8 - continued

	I		II	
	Percent of Students		Percent of Students Combined Data	
	CONT	MAST	CONT	MAST
12. If made available, I would select sections of other basic studies courses which were taught using the mastery strategy				
a. true----------		82		
b. false----------		18		

Time Study

Hypothesis 7: The time spent by the experimental group in the laboratory is not different from the time spent by the control group.

Result 7: The hypothesis was rejected.

Table 9 gives a summary of the comparable time investments for the control and the experimental groups. Lab time refers to the average time spent per student per week in independent study and was obtained from the students' time card. The time spent in independent study (lab) was significantly higher for the experimental group. Out of class time was estimated using the student's response on the questionnaire (item 9). Out of class time was not significantly different for the two groups. Zero time refers to the average number of students cutting the independent study session per week. It was found that significantly more students in the control section missed the session each week than those in the experimental group. In summary, the lab time was different presumably for three reasons.

1) Students in the experimental section spent more time on each unit studying the material and preparing for the checktests.

2) Some time was required to take the checktests which was included in students' time commitment.

3) The students in the experimental group were more regular in their attendance in independent study and had fewer average cuts per week.

It may be that the difference of the two groups on the BAT was because the mastery strategy was successful in getting students to class who otherwise would not have attended.

Table 9. Time Comparisons

	Lab Time	**Out of Class	Zero Time
CONT	2.08	1.35	13.7%
MAST	3.13	1.27	7.7%
Significant	*yes	no	*yes

*Significant at the 95% confidence level

**Reported by students on a questionnaire

Students Excluded from Study

Hypothesis 8: The proportion of the students excluded from the study was the same for the control and the experimental group.

Result 8: The hypothesis was not rejected.

There were some students who were initially enrolled in the sections but were not included in the study. A student was excluded if he did not complete all of the data gathering instruments at the assigned time. Generally, exclusion was due to a student either dropping the course or missing one or more of the four examinations. Neither the difference in the total number of students excluded from the study (Column A-B, Table 10) nor the number of students dropping the course was significant (Column A-C) when the chi-square test for significance was applied.

Table 10. Students Excluded from the Study

	A Enrolled	B Excluded	C *Drops
CONT	183	20	13
MAST	163	13	8

CONCLUSIONS

1. The mastery strategy is effective in improving achievement of students in a large general biology course.

2. The mastery strategy was effective in improving achievement on four of the eleven individual topics included in the study; namely, chemistry, cell division, plant reproduction, and animal reproduction. The control section failed to significantly excel on any of the topics.

3. The best predictor of achievement in the general biology course was the high school percentile rank. It was superior to the pretest and various components of the American College Test (ACT).

4. The mastery strategy was not significantly more effective to either low ability or high ability students. However it was more effective with a middle ability group. The ability grouping was based on the high school rank.

5. The mastery strategy did not significantly affect the grade distribution; however, there appears to be an upward skewing of grades in the experimental section.

6. The experimental group devoted significantly more time to the course than the control group.

7. Student opinion indicates the experimental group accepted the mastery strategy as useful.

8. Students in the control and the experimental group did not drop the course at different rates.

IMPLICATIONS

The mastery strategy has exciting possibilities. Additional research is needed to evaluate various formats of the strategy itself.

1) A question which evolved during this study concerns the validity of checktests as tools to evaluate whether or not student achieved the objectives. The checktests must be short enough to be practical but long and complete enough to be reliable indicators of achievement. It seems reasonable to expect that a student who achieves the minimum 80% level on the checktests of the experimental section scored above 75% on the BAT; consequently the checktests should be restructured in an attempt to make them more reliable tools.

2) The best predictor of success in biology proved to be the high school rank with a probability indicator of less than .20. A more reliable criterion is needed in order to identify potential low achievers in biology. Even though the results in this study did not show that the potentially low achievers were helped significantly more by the mastery strategy there is enough evidence to suggest that if a more reliable predictor was available as a criterion the results may be different. The research should be repeated using that criterion as the basis for dividing students into low and high ability groups.

3) The mastery strategy for learning can be adapted to most any subject. For the instructor the strategy represents a philosophy that is healthy for all levels of education, namely, that he can become a teacher that can help his students to become "successful students". For the students the strategy represents a philosophy that is also healthy, namely, that he can achieve at a level to become a "successful student". In either case nothing has been compromised at the expense of sound educational practice or good common sense. All that is required is a restructuring of current educational methods.

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APPENDIX A-THE AUDIO-TUTORIAL SYSTEM

The audio-tutorial program at Wisconsin State University-La Crosse was initiated during the 1966-1967 school year to teach a four-credit course, Principles of Biology. Teaching materials for the course were developed by Sparks and Nord with major emphasis placed on basic concepts of biology. The script for the audio-tapes, an instructor's guide and the student's study guide have been published and made available commercially (Sparks & Nord, 1968). The course is designed to be completed in one semester with course content and teaching materials divided into weekly units.

The course includes three sessions similar to the organization of the Purdue program (Postelthwait et al. 1969).

1. A General Assembly Session (GAS)
2. A Small Assembly Session (SAS)
3. An Independent Study Session (ISS).

Each of the components is designed to accomplish unique functions. These major study sessions are utilized in this study and are described below.

General Assembly Session

All students attend a general assembly session for one hour on Monday mornings. The enrollment in each section of GAS is limited to 150-180 students depending on the size of the assembly auditorium. The two faculty members who initiated the course are in charge of these sessions. During these meetings directions are given, announcements are made and other general administrative duties are accomplished. One hour examinations or ten minute quizzes are administered at each session. Selected films, related to the topics currently under study, are periodically shown. Also, unique features or requirements of the upcoming unit are brought to the attention of the students. Because testing is done during this session, student attendance is mandatory.

Independent Study Session

The independent study session takes place in a laboratory-like learning center which is specially designed so that a wide variety of teaching tools and techniques can be effectively employed.

The laboratory contains carrels in which a student can work individually and at his own pace. All carrels are identically furnished and contain the material to be used in completing the unit being studied. The items present in the carrel include a tape player, the week's tape, photographs, charts, specimens, glassware and a microscope. Materials which are too bulky or

too expensive to be placed in each carrel are available at a central demonstration table. Short films and demonstrations are also viewed at this central site.

The learning center is open from 8:00 a.m. to 10:00 p.m. during the first four days of the school week, and from 8:00 a.m. to 4:00 p.m. on Friday. The student can report to the learning center at his convenience and can stay as long as he wishes. He can repeat any portion of the unit as many times as he feels necessary. This allows him to make adjustments in his study schedule in response to the pressure of other campus activities.

Upon entering the study center the student assigns himself to a specific carrel by filling out and filing a student record card. When the student decides to leave the study center, he notes the time of departure on the record card and returns it to a storage box.

The activities of the student in the learning center are directed by the voice of an instructor on the audio tape. The student controls the speed at which the tape is played and can also rewind it for a repeat of the material. The first thing a student might hear when he listens to the tape is a brief lecture which introduces the topic for that week. He might then be asked to read appropriate passages from his textbook or from other sources. This may be followed by a directive to observe a demonstration, perform an experiment or observe a film or other visual presentation.

As an additional aid in studying, the student receives a weekly objective-question program which guides him to the important concepts in the unit. Each student also possesses a study guide which furnishes additional information regarding all demonstrations and experimental activities and is where results of laboratory activities are recorded.

An instructor is on duty at all times in the learning center so that the student has immediate access to assistance when he needs it. The student-instructor contact is as little or as great as the learner desires.

The audio tape scripts and the final recordings are prepared by the instructors responsible for the course. During script production, it is necessary to insure that materials are properly sequenced since no arbitrary division into reading assignment, laboratory session and lecture session is made. Rather, the learning experience deemed to be most valuable for teaching a fact or a concept is inserted at the point where the instructor believes it would foster maximum student understanding.

One of the most significant features of the organization of the independent study session is that the responsibility for learning is placed on the individual student. Many aids to learning are provided; if the individual chooses not to take advantage of the circumstances, the decision and responsibility are his.

Small Assembly Session

These one-hour sessions meet late in the week and have an enrollment

of thirty or fewer students. The format for these sessions varies greatly since it is determined by the assigned instructor. During these sessions, major emphasis may be given to reviewing the material studied in the learning center, the objective-question programs, or supplementary topics.

While the factual information and the basic principles of biology are learned in the independent study sessions, the small assembly sessions are used to relate those facts and concepts to the student's experiences. In addition, attempts can be made during these sessions to create or change ideas and opinions.

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APPENDIX B-CHECKTESTS

Sample checktests are provided for one unit. This unit was divided into two separate conceptual minicourses (Part A and Part B). A student could receive any one of four checktest forms as an evaluation tool.

Name _____
Last First

CHECK TEST WEEK 2 - Part A - Form 1
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

_____1. The chemical symbol "N" refers to what element? (2)

_____2. In the following chemical statement, how many sulfur atoms are represented? $5C_4HS_2O$

_____3. In the above statement how many molecules are represented? (4)

_____4. The molecular weight for the molecule in question two is _____. (6)

C = 12, H = 1, S = 32, O = 16, N = 14

_____5. The pH of a solution was changed from 8 to 7. Which one of the molecules below was probably added? (7)

a. H^+Cl^- b. Na^+OH^-

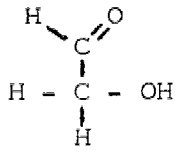
_____6. Since many substances dissolve in water it must be a good _____. (8)

Name_____
Last First

CHECK TEST WEEK 2 - Part A - Form 2
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

_____1. The chemical symbol for sulfur is____. (2)

_____2. The molecular formula for the structure below is_____. (4-5)



_____3. The molecular weight for the molecule in question two is_____. (6)

C = 12, H = 1, O = 16, N = 14

_____4. Write a structural formula for the molecule below. (5)

CH_2O

_____5. Which of the following would be most abundant in a solution with a pH of 4? (7)

a. H^+ b. OH^-

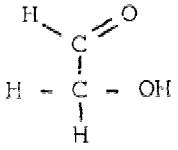
_____6. An organic molecule will have mostly (what kind) chemical bonds. (9)

Name_____
Last First

CHECK TEST WEEK 2 - Part A - Form 1
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

_____1. The four most abundant elements in living matter are_____, _____, _____, _____. (1)

_____2. The lines between the upper C and the O represent (how many) chemical bond(s). (5)



_____3. The molecular weight of the molecule noted in question two is_____. (6)

C = 12, N = 14, H = 1, O = 16

_____4. The pH of a solution was increased from 4 to 6. What was probably added? (7)

a. H^+ b. OH^-

_____5. The most abundant molecule in your body is___. (8)

_____6. Is the molecule in question two organic or inorganic?

Name_____
Last First

CHECK TEST WEEK 2 - Part A - Form 4
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

_____1. The type of chemical bond formed when unlike charges attract each other is called an_____ chemical bond. (1)

The chemical statement $7Na^{+}SO_4^{-}$ appears in a text book. Use it to answer questions 2-6.

_____2. How many oxygen atoms are there <u>per molecule</u>? (2-4)

_____3. What does the Na stand for? (2)

_____4. Is the substance organic? (9)

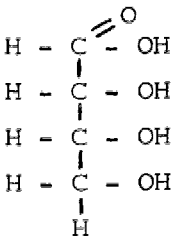
_____5. Categorize the substance as an acid, a base, or a salt. (7)

_____6. The molecular weight of the substance is____. (6)
Na = 23, S = 32, O = 16

Name_____
Last First

CHECK TEST WEEK 2 - Part B - Form 1
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

Use the formula at the right to answer the following questions.



_____1.-2. What two functional groups are present? (10)

_____3. Classify the molecule according to the number of carbon chains. (11)

_____4. Classify the molecule according to the number of carbon atoms. (11)

_____5. If you were to use biochemical tests on the substance, which tests would be positive? (13)

monosaccharide
polysaccharide
pentose
aldehyde
ketose

_____6. Following is the results of some biochemical tests. What is the substance? (13)

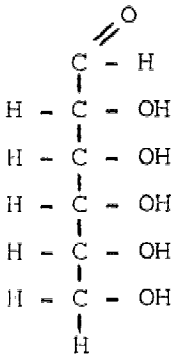
⁻monosaccharide, ⁻ketose, ⁻pentose, ⁻aldehyde,

⁺polysaccharide.

Name_____
Last First

CHECK TEST WEEK 2 - Part B - Form 2
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

Use the formula at the right to answer the following questions.



_____1.-2. What two functional groups are present? (10)

_____3. Classify the molecule according to the number of carbon chains. (11)

_____4. Classify the molecule according to the number of carbon atoms. (11)

_____5. If you were to use biochemical tests on the substance, which tests would be positive? (13)

Monosaccharide
polysaccharide
pentose
aldehyde
ketose

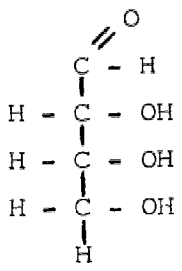
_____6. Following is the results of some biochemical tests. What is the substance? (13)

$^{+}$pentose, $^{+}$monosaccharide, $^{-}$ketose, $^{-}$polysaccharide, $^{-}$aldehyde

Name_____
Last First

CHECK TEST WEEK 2 - Part B Form 3
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

Use the formula at the right to answer the following questions.



_____1.-2. What two functional groups are present? (10)

_____3. Classify the molecule according to the number of carbon chains. (11)

_____4. Classify the molecule according to the number of carbon atoms. (11)

_____5. If you were to use biochemical tests on the substance, which tests would be positive? (13)

monosaccharide
polysaccharide
pentose
aldehyde
ketose

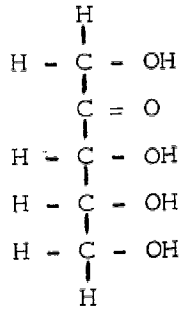
_____6. Following is the results of some biochemical tests. What is the substance? (13)

$^{-}$monosaccharide, $^{-}$pentose, $^{+}$ketose, $^{-}$polysaccharide, $^{-}$aldehyde

Name_____
Last First

CHECK TEST WEEK 2 - Part B - Form 4
Mastery: One incorrect answer permitted
The number in the parenthesis corresponds to the objective being tested.

Use the formula at the right to answer the following questions.



_____1.-2. What two functional groups are present? (10)

_____3. Classify the molecule according to the number of carbon chains. (11)

_____4. Classify the molecule according to the number of carbon atoms. (11)

_____5. If you were to use biochemical tests on the substance, which tests would be positive? (13)

monosaccharide
polysaccharide
pentose
aldehyde
ketose

_____6. Following is the results of some biochemical tests. What is the substance? (13)

$^{-}$monosaccharide, $^{-}$ketose, $^{-}$pentose, $^{-}$polysaccharide, $^{+}$aldehyde

APPENDIX C-OPERATIONAL GUIDELINE FOR BIOLOGY 100 SECTION 13 SPRING 1971

You are in a section of Biology 100 which will be using the mastery strategy for the remainder of the semester. Why are we using this method? Please understand that we are trying this innovation in an attempt to help you learn more effectively and help you to improve your marks.

We have evidence that the AT system has significantly improved student achievement. However, many students do not obtain the full potential of the AT system because they continue to operate much like they would in a conventional lecture course (taking notes to study later in the dorm). Educational research reveals that achievement is enhanced when major units of study are broken into smaller topics and each small segment of the unit is mastered in sequence. This learning concept is the basis for the format to be used by this section. After you have been in the course for awhile the rationale for its operation will become more evident. You will continue this week just like during week one with a few important exceptions. Below is a description of how you will need to work using the Mastery system.

1. Go to the laboratory at a time you select and check in just like last week.

2. Note study guide corrections which are posted on the bulletin board; the unit has been divided into parts. Make these changes in <u>your</u> study guide.

3. Pick up a set of objectives. <u>Note they are divided into Parts A & B just like your study guide</u>.

4. Go to your booth and look over your objectives briefly.

5. Begin the unit following the program on the tape just like last week.

6. Work until you come to the end of Part A in your study guide.

7. Make sure you achieve all of the objectives in Part A of your objective program. If you cannot achieve all of them, get help from the instructor concerning the portion of the objectives that you cannot achieve.

8. When you are confident that you can achieve the objectives, ask the instructor for check-test Part A. It will take about 3-5 minutes for you to complete. The instructor will grade the test immediately.

9. The number of <u>incorrect</u> answers permitted will be listed at the top of the check-test.

10. If you do not exceed the number of incorrect answers you will be given credit for mastering Part A and begin Part B. Go to number 13 on this handout.

11. If you exceed the number of incorrect answers permitted, you will need to review or repeat Part A and retake the check-test using another form for Part A.

12. Should you again fail to achieve the required number of correct answers you will be asked to sign up for "Group Therapy" with an instructor which will meet at a later time. (He will try to help you with the material and then decide whether or not to give you credit for the check-test). After signing up proceed immediately to Part B of the unit. Do not wait until after the group session to finish Part B because that will be next week and a new unit will be set up in the laboratory.

13. When you are confident you can achieve the objectives related to Part B, ask the instructor for check-test Part B. The rules are the same as before (See 9, 10, 11, and 12 above).

Section 13 will not take weekly quizzes like the other sections of Biology 100. Instead you will have an opportunity to earn 100 points using the check-tests in the laboratory. There will be approximately 30 check-tests during the semester; if you satisfactorily complete all 30, you will receive all 100 pts. A missed check-test will penalize you as follows:

one miss	95
two misses	90
three misses	80
four misses	70
five misses	60
six misses	50
seven misses	40
eight misses	30
nine misses	20
ten misses	10
eleven or more	0

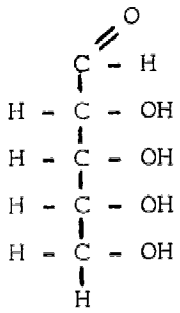
You will take exams, attend small assembly and general assembly just like the other sections of Biology 100.

APPENDIX D-BIOLOGY ACHIEVEMENT TEST

The following series of objective questions is a sample of the items included in the Biology Achievement Test.

Select the one most correct answer. Darken the space below the corresponding letter on your answer sheet. If you change a choice, erase cleanly.

Use the diagram at the right and answer the following four questions.



1. The substance is a:

   a. carbohydrate
   b. protein
   c. lipid
   d. nucleic acid

2. The formula is a:

   a. structural formula
   b. molecular formula

3. The molecular weight is:

   C = 12 N = 14 O = 16 H = 1

   a. 43
   b. 29
   c. 150
   d. none of the above

4. The substance would give a positive

   a. ketose test
   b. pentose test
   c. lipid test
   d. protein test

==== ==== ==== ==== ==== ==== ==== ==== ====

Four categories of food stuffs (a-e) are listed below. Place the numbered substances in one of the categories, the categories may be used more than once.

   a. carbohydrate
   b. lipid
   c. protein
   d. nucleic acid
   e. none of the above

5. _____ starch

6. _____ DNA

7. _____ polymerase

8. _____ cholesterol

9. _____ table salt

10. _____ corn oil

11. _____sucrose

==== ==== ==== ==== ==== ==== ==== ==== ====

12. Fatty acids contain:

a. C
b. H
c. O
d. all of the above

13. Glucose contains:

a. amino groups
b. alcohol groups
c. high energy bonds
d. none of the above

14. Carbohydrates contain:

a. only C, H, O and nothing else
b. only C, H, O, N and nothing else
c. only C, H, O, N, P and nothing else
d. none of the above

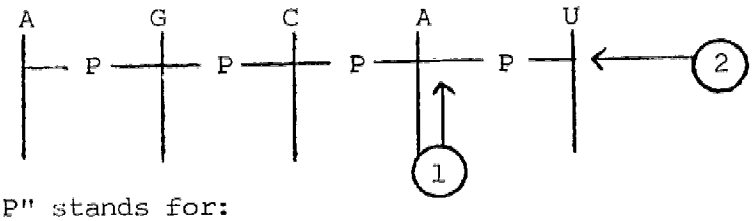
15. The element found in proteins but not carbohydrates is:

a. Na
b. C
c. O
d. N

16. Thymine could be found in:

a. starch
b. diastase
c. salad oil
d. DNA

Use the diagram below to answer the following 5 questions.



17. The letter "P" stands for:

a. potassium
b. high energy bond
c. phosphate
d. proton

18. The letter "G" stands for:

a. guanine
b. glucose
c. CO_2
d. carboxyl group

19. The arrow labeled number 1 points to a line indicating:

a. ribose sugar
b. a nitrogen base
c. an amino acid
d. a chemical bond

20. The arrow labeled number 2 points to a line indicating:

a. ribose sugar
b. a nitrogen base
c. an amino acid
d. a chemical bond

21. The entire diagram represents a molecule of:

a. RNA
b. DNA
c. a protein
d. a lipid

++++ ++++ ++++ ++++ ++++ ++++ ++++ ++++ ++++

22. A high energy chemical bond is represented by:

a. a straight line
b. the letter "P"
c. a wavy line
d. a dotted line with an arrow on the end of it

Use the chemical statement below to answer the following 3 questions.

$$5C_6H_{12}O_6$$

23. The substance probably is a:

a. carbohydrate
b. protein
c. lipid
d. nucleic acid

24. How many carbon atoms are represented by the statement?

a. 1
b. 5
c. 6
d. 30
e. none of the above

25. How many molecules are represented by the statement?

a. 1
b. 5
c. 6
d. 30
e. none of the above

= - =

For questions 26 through 33 select the correct answer from the choices on the right. Each choice may be used more than once.

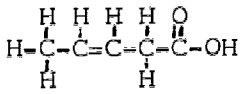
26. It contains the element sulfur.

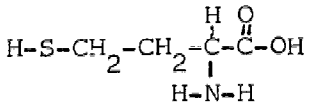
27. It contains an amino group.

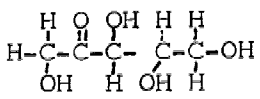
28. It can form peptide bonds with others like it.

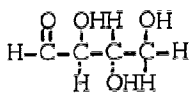
29. It contains a ketone group.

30. It contains a covalent bond with 2 pairs of electrons shared between 2 carbon atoms.

a. 

b. 

c. 

d. 

e. none of the above

31. It contains an aldehyde group.

32. It is a pentose sugar.

33. It is a fatty acid.

**** **** **** **** **** **** **** **** ****

34. Which molecule would contain the greatest number of carbon atoms:

a. glucose
b. maltose
c. sucrose
d. starch

35. The most abundant element in living matter by weight is:

a. oxygen
b. calcium
c. nitrogen
d. water
e. iron

36. The results of a series of tests were as follows:

$^{+}$monosaccharide; $^{+}$pentose; $^{+}$aldose; $^{-}$ketose; $^{-}$polysaccharide

The substance could be:

a. glucose
b. fructose
c. maltose
d. ribose

Use the reaction below to answer questions 37-39.

$$6\ CO_2 + 6\ H_2O + \text{Energy} \longrightarrow C_6H_{12}O_6 + O_2$$

37. The equation above is not balanced. To balance the equation_____ would be required.

a. more CO_2
b. more $C_6H_{12}O_6$
c. more H_2O
d. more O_2

38. If the reaction required a catalyst it most likely would be a:

a. lipid
b. salt
c. protein
d. carbohydrate

39. The reaction is:

a. endergonic
b. exergonic

**** **** **** **** **** **** **** **** ****

40. You are given an unknown. You perform a polysaccharide test which is positive; a test for aldehyde groups which is negative; a test for ketone groups which is negative; a Sudan IV test which is positive; and a test for peptide bonds which is negative. You conclude that the unknown contains:

a. a starch and ribose
b. protein and cellulose
c. fat and sucrose
d. starch and fat

41. An ion must:

a. have a functional group present
b. have an electrical charge
c. form a covalent bond in a chemical change
d. have an equal number of electrons and protons

42. If a scientist's experimental results contradict his hypothesis, what should he do?

a. forget the results
b. form a new hypothesis
c. change the data to fit the hypothesis
d. keep experimenting until he gets the results he wants

43. All enzymes known in nature are:

a. carbohydrates
b. lipids
c. proteins
d. proteinases

44. If the sequence of bases in one strand of DNA is TGAACCT, the sequence in the opposite strand would be:

a. CAGGTTC
b. ACTTGGA
c. GTCCAAG
d. ACUUGGA

45. The sugar deoxyribose is a component of:

a. RNA
b. DNA
c. protein
d. maltose
e. none of the above

46. Which of the following would be a salt?

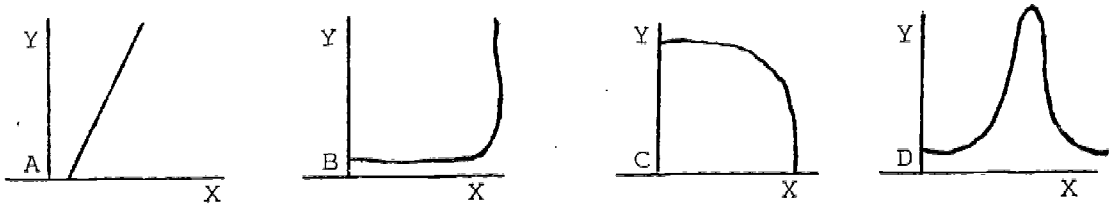
a. NaOH
b. KCl
c. HCl
d. H_3PO_4

47. Energy + ADP + phosphate $\longrightarrow$ ATP

The above reaction is:

a. exergonic
b. endergonic
c. neither
d. both

Use the graphs below for questions 48 and 49.



48. Which graph shows the effect of temperature on the rate of an enzymatically catalyzed reaction?

a. A
b. B
c. C
d. D
e. none of the graphs

(Let the X axis represent the temperature and the y axis the reaction rate)

49. Which graph shows the effect of enzyme concentration on the rate of an enzyme reaction?

a. A
b. B
c. C
d. D
e. none of the above

(Let the x axis represent the enzyme concentration and the y axis the reaction rate)